DERIVATION OF MID-INFRARED (5-25μm) OPTICAL CONSTANTS OF SOME SILICATES AND PALAGONITE

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Recent reports concerning the mid-infrared reflectance properties of silicates [1,2,3] coupled with recent observations of the Earth [4] and other planets [5,6,7,8,9,10] in the mid-infrared and the planned Thermal Emission Spectrometer scheduled as an instrument to be included on the Mars Observer all illustrate the increasing interest in the optical properties of materials in the mid-infrared and their direct application to remote sensing observations of other planetary surfaces. As the laboratory and observational data increase they will ultimately be modeled to aid in the understanding of the composition mineralogy, and distribution of the surface and atmospheric constituents on these bodies.

In order to facilitate such quantitative analyses, knowledge regarding the optical constants (real (n) and imaginary (k) indicies of refraction) of a wide variety of pertinent materials is required. Examples of the application of such quantitative analyses to the interpretation of martian surface and atmospheric constituents, based on the optical constants of minerals, are presented in [8,11,12].

Optical constants can be readily derived from polished surfaces of cohesive materials using standard geological thin sectioning and polishing techniques. The mid-infrared optical constants of only a few specific silicate minerals are available in the literature [12,13,14,15]. Additionally, optical constants have been determined for a number of specific rock types including silicates [14,16] and limestone [17]. Recently optical constants for palagonite, typically a poorly characterized mineralogical assemblage resulting from the alteration of basaltic glass, were presented for a limited wavelength range [18].

This study was initially conceived in order to aid in the interpretation of martian surface and atmospheric aerosol mineralogy. As a result, the minerals included are biased toward samples which represent hydrated and hydroxylated silicates. These include: 1)the Al and Mg end members of the 1:1 layer lattice silicates, kaolinite and serpentine, respectively; 2)an Al-bearing 2:1 layer lattice silicate, pyrophyllite; 3)the Mg and Al smectite clays saponite and montmorillonite, respectively; and 4)a palagonite, typically a poorly characterized alteration product of basaltic glass. Due to their physical particle size clays and other materials, such as palagonite, can not be prepared using typical preparation techniques. Yet in some cases, such as for Mars, these are the materials of perhaps the greatest interest. In order to obtain a suitable sample of these less cohesive materials for the laboratory measurements a KBr pellet die was used and a pellet of the pure sample was prepared. The powders were previously separated by dry sieving and roughly 200 mg of the finest grain size fraction ($\leq 38\mu m$) placed in the KBr die. The die was placed in a hydraulic press and the pressure increased to a maximum of roughly 0.5 to 7 Kbars on the 12mm die, depending upon the sample, and held at that pressure for five minutes. For all clays and the palagonite this produced a pellet with highly reflective surfaces at visible wavelengths.

The reflectivities of all samples were determined by placing them at the focus of a near-normal reflectance attachment located in a Fourier transform spectrometer. The data from each sample was ratioed to the data obtained from a first surface aluminum mirror which was conservatively assumed to have a reflectance of 0.96 at all wavelengths. Data were collected from 4000 to 400 cm^{-1} (2.5-25μm) with a constant spectral resolution of 4 cm^{-1} however, due to an increase in multiple scattering optical constants were derived only in the 2000-400 cm^{-1} (5.0-25μm) region.

To derive the optical constants of a material as a function of wavelength we used the commonly employed technique of dispersion analysis [13,14,15,16,17,19] which describes n and k as the contributions due to a sum of classical oscillators and relates them via Fresnel's equations for non-normal incidence, to the measured near-normal reflectivity. Non-linear least squares techniques was used to minimize the differences between the observed and calculated reflectivities. In our analyses we varied both the total number of oscillators and the high frequency dielectric constant (ε_∞) to most accurately describe the measured reflectances. The final values determined represent averages of several model fits to each data set using the same number of oscillators but varying ε_∞. In all cases we required oscillator central wavelengths to fall within the range of our observations, and the oscillator strengths and widths to be non-negative. The kaolinite and serpentine data were fit with 15 and 10 oscillators, respectively, while the pyrophyllite data required 17 oscillators. The saponite data needed 8 oscillators and the montmorillonite data 15 oscillators. The palagonite data were described by 7 oscillators. For those minerals which contain abundant water, the smectites and palagonite, we were able to include an oscillator for the $\approx$6.25μm H-O-H bending mode.

Overall we found our results were extremely consistent with values previously determined for similar materials [12,15,18] but some discrepancies remain. These discrepancies may be due to differences in analysis techniques, in one study [12] only qualitative assessment of a best fit criteria was used, in another [18] transmission measurements were used along with the assumption that the real index of refraction was constant, and in another study [15] additional measurements at longer wavelengths were included. The discrepancies may also arise from differences in sample composition between the various studies.

References: [1]Salisbury et al., USGS Open-File Report 87-263, 1987; [2]Salisbury & Walter, JGR, 94, 9192, 1989; [3]Walter & Salisbury, JGR, 94, 9203, 1989; [4]Bartholomew et al., J. Remote Sens., 10, 529, 1989; [5]Potter & Morgan, Proc. 12th Lunar Planet. Sci., 703, 1981; [6]Tyler et al., GRL, 15, 808, 1988; [7]Roush et al., Lunar Planet. Sci. Conf. XX, 928, 1989; [8]Pollack et al., JGR, 95, 14,595, 1990; [9]Lucey et al., Bull. Am. Astron. Soc., 21, 970, 1989; [10]Roush et al., submitted to Lunar Planet. Sci. XXII, 1991; [11] Aronson & Emslie JGR, 80, 4925, 1975; [12]Toon et al., Icarus, 30, 663, 1977; [13]Spitzer & Kleinman, Phys. Rev., 121, 1324, 1961; [14]Aronson & Strong, Appl. Opt., 14, 2914, 1975; [15]Mooney & Knacke, Icarus, 64, 493, 1985; [16]Pollack et al., Icarus, 19, 372, 1973; [17]Querry et al., Appl. Opt., 17, 353, 1978; [18]Crisp & Bartholomew, Lunar Planet. Sci. XX, 201, 1989; [19]Toon et al., JGR, 81, 5733, 1976;